REMARKS

OFFICE ACTION SUMMARY

In the Office Action dated July 9, 1999, the Examiner made the following objections and rejections to allowance of the instant patent application:

ITEM 1 - The drawings were objected to as failing to include reference to numeral 21 that is mentioned in the description (Office Action, paragraph 7);

ITEM 2 - The drawings were also objected to as failing to show every feature of the invention as specified in apparatus claims 16-29 (Office Action, paragraph 8);

ITEM 3 - The disclosure is objected to because of certain informalities at the following pages/lines: 3,1; 2,13; 14, 15; 15,6; 16, 2; 18, 10 (Office Action, paragraph 9);

ITEM 4 - Claim 1 is rejected under 35 U.S.C. §112, first paragraph, as not enabling anything beyond electrodeposition, whereas the claim language references "depositing" (Office Action paragraph 11);

ITEM 5 - Claim 1 was deemed indefinite under 35 U.S.C. §112, second paragraph since the Examiner does not understand the thickness standard set forth in claim 1 (Office Action, paragraph 13);

ITEM 6 - Claim 27 was rejected under 35 U.S.C. §112, second paragraph since the Examiner is not clear as to what is meant by the addition of a further layer of copper over the conductive ultra-thin seed layer using an acidic copper bath (Office Action, paragraph 13);

ITEM 7 - Claim 9 was rejected under 35 U.S.C. §112, second paragraph, since there is purportedly no antecedent basis for the term "complexing agent". The Examiner has indicated that claim 9 should probably be dependent on claim 4 (Office Action, paragraph 13);

ITEM 8 - Claims 1-3, and 7 are rejected under 35 U.S.C. §102(b) as being anticipated by USP 5,549,808 (Office Action, paragraph 15);

ITEM 9 - Claims 16 and 17 are rejected under 35 U.S.C. §102(b) as being anticipated by USP 5,882,498 (Office Action, paragraph 16);

ITEM 10 - Claim 6 is rejected under 35 U.S.C. §103 as being unpatentable over USP 5,549,808 (Office Action, paragraph 18);

ITEM 11 - Claims 4-5,9-10, and 12 are rejected under 35 U.S.C. §103 as being unpatentable over USP 5,549,808 and further in view of USP 5,151,168 (Office Action, paragraph 20);

ITEM 12 - Claims 30-32, 35-37, 39-40, and 42 are rejected under 35 U.S.C. §103 as being unpatentable over USP 5,549,808 and further in view of USP 5,151,168 (Office Action, paragraph 21);

ITEM 13 - Claims 15 and 46 are rejected under 35 U.S.C. §103 as being unpatentable over USP 5,549,808 and USP 5,151,168 and further in view of USP 5,882,498 (Office Action, paragraph 22);

ITEM 14 - Claims 18-23 and 27-29 are rejected under 35 U.S.C. §103 as being unpatentable over USP 5,882,498 and further in view of USP 5,151,168 (Office Action, paragraph 23);

ITEM 15 - Claims 24-26 are rejected under 35 U.S.C. §103 as being unpatentable over USP 5,549,808 and 5,151,168 and further in view of USP 5,882,498 (Office Action, paragraph 24);

ITEM 16 - Claims 9,11, and 13 are rejected under 35 U.S.C. §103 as being unpatentable over USP 5,549,808 and USP 4,576,689 (Office Action, paragraph 25);

ITEM 17 - Claims 41, 43, and 44 are rejected under 35 U.S.C. §103 as being unpatentable over USP 5,549,808, USP 4,576,689 and USP 5,151,168 (Office Action, paragraph 26).

NON-ART REJECTIONS/OBJECTIONS

ITEMS 1 and 2 are directed to the drawings provided in the present application. To overcome the Examiner's objections, Applicant has submitted herewith a Request for Approval of Drawing Changes in which Figure 2B has been amended to identify the spikes 21. Additionally, corrections have been made to the drawings to add reference numeral 23 and to correct the leave line for reference numeral 22. Further, Applicant is submitting herewith Figure 7, which the USPTO apparently did not receive in the application as originally filed. Figure 7 has been drawn to track the language of the specification set forth on pages 20-21 and only includes block diagram representations of the tool/tools described on those pages. As such, Figure 7 does not at any new matter to the present application. Applicant therefore respectfully requests withdrawal of the objections/rejections set forth in ITEMS 1 and 2.

In connection with ITEM 3, Applicant has amended the specification to incorporate the corrections suggested by the Examiner as well as some changes that were noted by Applicant's

representative during review of the specification. Accordingly, the objections set forth in connection with ITEM 3 have been addressed.

Applicant respectfully submits that the rejection set forth in ITEM 4 is unwarranted, particularly in view of the language of the specification, claim 1 as originally filed, and the meaning of the term "deposition" within the art of microfabrication. At p. 11, lines 8 through 10, the specification of the present application describes the enhancement of the ultra-thin seed layer stating: "To this end, the semiconductor workpiece is subject to a subsequent process step in which a further amount of copper 18 is applied to the ultra-thin seed layer to thereby enhance the seed layer." (emphasis added). Notably, this sentence does not expressly limit the enhancement step to an electroplating process but, rather, describes the process step as one in which a "further amount" of a metal (here, copper in the preferred embodiment) is added to the ultra-thin seed layer. Further, claim 1 as filed forms a part of the original disclosure of the patent application, and describes the process step associated with the seed layer enhancement as a "deposition" process. Within the microfabrication industry, there are a number of metal "deposition" processes that are well-known and that, given the teachings of the present application, would be recognized as being suitable for use in the seed layer enhancement step. Many of these deposition processes are identified in the present application in connection with the deposition of the ultra-thin seed layer and include electrochemical deposition, electrolytic deposition, physical vapor deposition, and chemical vapor deposition. The seed layer enhancement step of claim 1 therefore should not be limited to the electrolytic enhancement process that Applicant has chosen to describe in detail as his preferred embodiment. Rather, given the language of the present application as filed and the knowledge of metal deposition techniques possessed by those in the microfabrication industry, a broader view of

the teachings of the specification is warranted. Applicant therefore requests reconsideration of the rejection of claim 1 set forth in ITEM 4.

In connection with the rejection set forth in ITEM 5, Applicant has amended claim 1 to clarify the locations at which the thickness of the enhanced seed layer is to be measured to make the proper ratio determination. This ratio is described in the specification at pages 11-12 of the present application. More particularly, claim 1 has been amended to indicate that the thickness of the enhanced seed layer as measured at the sidewalls of the micro-recessed structures is at least 10% of the nominal thickness of the enhanced seed layer at the exteriorly disposed surface of the workpiece in which the micro-recessed structures are formed. Further broadening language is included in claim 1 so as not to exclude from the scope of claim 1 any seed layer enhancement techniques that fail to completely enhance the seed layer in each and every micro-recessed structures of the workpiece. It is readily recognized that real-world microfabrication processes do not always provide a 100 percent yield of devices that from a microelectronic workpiece. Some of the factors that affect this yield are set forth at pages 11 and 12 of the present application. Applicant therefore respectfully requests reconsideration of the rejection set forth in ITEM 5.

Applicant has amended claim 27 to make it clear that the further layer is added over the enhanced seed layer, not directly on the ultra-thin seed layer prior to its enhancement. Accordingly, reconsideration of the rejection of ITEM 6 is respectfully requested.

REJECTIONS BASED ON PRIOR ART

ITEMS 8-17 are directed to rejections that are based on the prior art of record. To this end, all of the independent claims of the present application stand rejected as being unpatentable over the art of record; principally, USP 5,549,808 (the '808 patent) and USP 5,882,498.

Applicant submits, however, that the independent claims of the present application, as presently amended, are patentably distinguishable over the art of record. Further, Applicant has added new claims that are likewise patentably distinguishable over the art of record.

The present invention is directed to apparatus and processes for depositing a metal on the surface of a microelectronic workpiece. In the microfabrication industry, metal deposition may take a number of forms. For purposes of the following discussion, only two of these forms will be discussed: 1) those in which the metal is deposited in and is used to fill micro-recessed structures in the surface of the microelectronic workpiece (e.g., line and via structures that are formed in the surface of the workpiece and that are subsequently filled with metal to provide the metal interconnect of, for example, an integrated circuit, such as found in USP 5,882,498 to Durbin); and 2) those in which the metal is deposited over a substantially smooth surface of the workpiece (e.g., the copper layer of USP 5,549,808 to Farooq).

In each instance, deposition of the principal metal forming the bulk of the desired metal structure during an electroplating process first requires application of a conductive seed layer over the surface of the microelectronic workpiece. The characteristics of this conductive seed layer may significantly increase or decrease the quality of the principal metal film that is electroplated on the conductive seed layer. Generally stated, electroplating on thicker seed layers provides principal metal films of higher quality when compared with thin seed layers. Accordingly, conventional wisdom in the microfabrication industry mandates thick seed layers for high-quality of the electroplated film. However, as the sizes of micro-metal structures decrease, so must the thickness of the seed layers used in electroplating the metal from which they are formed.

The requirement for a reduction in the seed layer thickness gives rise to its own set of problems. Many of these problems are discussed at pages 10-11 of the present application. Such problems include the inability to provide a continuous metal seed layer over the surfaces of the workpiece that are to be electroplated. Rather, ultra-thin seed layers often include voids at which electroplating will not take place (see Figures 2A to 2F of the present application). Further, there are often uniformity problems associated with ultra-thin seed layers that give rise to non-uniformities in the subsequently electroplated metal layer.

In accordance with the present invention, an ultra-thin metal seed layer is deposited on the surface of the workpiece using a deposition process, such as physical vapor deposition. The ultra-thin metal seed layer is then subject to a subsequent seed layer enhancement technique in which additional metal is added to the ultra-thin seed layer to provide an enhanced seed layer that is suitable for subsequent bulk electroplating of the principal metal that is used to form the metal micro-structure.

As presently disclosed in the application and claimed in various independent claims, enhancement of the seed layer can be defined in terms of various separately distinguishable criterion, all of which are supported in the specification as filed. First, as set forth in independent claim 1 as amended, as well as new independent claim 68, enhancement can be defined in terms of the amount of metal added to the ultra-thin seed layer prior to subjecting the workpiece to electroplating of the bulk of the principal metal (also see the description of the thickness standard as described above in this Response). Second, enhancement can be defined in terms of the need that exists for adding metal to the initial seed layer to render it suitable for subsequent bulk electroplating of the principal metal. In connection with this definition, enhancement may be described with reference to the initial thickness of the ultra-thin seed layer, noting that seed layer

enhancement may be needed for a first seed layer thickness value when the bulk electroplating of the principal metal is used to fill micro-recesses disposed in the surface of the microelectronic workpiece, while seed layer enhancement may not be needed unless the seed layer is below a second, greater seed layer thickness value when bulk electroplating of the principal metal takes place over a seed layer that has been deposited on a generally flat surface of the workpiece. This difference between the first and second seed layer thicknesses exists because it is more difficult to conformally deposit a thin seed layer in micro-recessed structures in the surface of the workpiece than it is to conformally deposit a thin seed layer over a generally flat surface of the workpiece. In view of this distinction, claims 16, 30, 49, 63 and 64, which are directed to a process in which the process is not limited to micro-recess filling, include language that limits enhancement to ultra-thin seed layers having a thickness that is ***less than*** 500 angstroms, while claims 1, 58 and 67, in which the process sequence is limited to micro-recess filling, include language that limits enhancement to ultra-thin seed layer thicknesses that are ***less than or equal to about*** 500 angstroms. Notably, the latter set of claims includes a larger upper limit for the thickness value, since seed layer thicknesses at least as large as 500 angstroms may exhibit a need to be enhanced before being suitable for subsequent electroplating of the bulk of the principal metal in the micro-recessed structures.

Third, seed layer enhancement may be defined in terms of the particular process sequence used to form the metal micro-structure. To this end, independent claims 68 and 69 are each generally directed to a process in which a metal is used to form an ultra-thin seed layer using a first deposition process. The ultra-thin seed layer is then enhanced to render it suitable for subsequent bulk electroplating of the principal metal by subjecting the ultra-thin seed layer to a second deposition process that is different than the first deposition process. The second

deposition process adds a layer of material to the ultra-thin seed layer that comprises the same metal that is used to form the ultra-thin seed layer. This enhancement step is followed by electroplating of the bulk of the principal metal used to form the metal micro-structure.

The Principal References - USP 5,549,808 and USP 5,882,498

The Examiner principally relies on the '808 and '498 patents to reject the claims of the application as set forth in ITEMS 8-17 above. Accordingly, each of these references is discussed here in detail.

The '808 Patent

The '808 patent is directed to a process for forming a multi-layer metallization structure on a microelectronic workpiece. At least two different structures for the multi-layer metallization are set forth. The first structure is described in connection with the process sequence illustrated in Figures 1-4. In this process sequence, the "seed layers" 12 and 14 are deposited over a substantially smooth surface of the workpiece. The first "seed layer" 12 is formed of a layer of chromium and the second seed layer 14 is formed of a layer of copper. It is in connection with this process sequence that the '808 patent states that the thickness of each of the seed layers 12 and 14 should be ***at least about*** 0.05 microns. (Emphasis added)

Although the '808 patent identifies the chromium layer as a "seed layer", the chromium layer does not function in that capacity. Rather, the chromium layer 12 is principally used as a barrier/adhesion layer and does not substantially assist in conducting electrical power for electroplating of the principal metal. As such, the chromium layer 12 does not function in the

capacity of a seed layer and, therefore, the subsequent application of the copper layer 14 does not constitute an enhancement of a seed layer. Rather, the deposition of copper layer 14 merely constitutes the application of a true seed layer over a barrier/adhesion layer.

Still further, the '808 patent does not suggest enhancement of the copper layer 14 prior to bulk electroplating of the principal metal 18. Rather, the workpiece is subject to a subsequent patterning process that is followed by an electroplating process in which metal 18 is directly electroplated on seed layer 14 without any intermediate enhancement of the seed layer 14.

Figure 5 of the '808 patent illustrates a further multi-level interconnect in which it appears that interconnect structures 31 and 131 have been formed so that they recede into openings in the respective insulating layers 20, 30. The '808 patent, however, does not set forth the manner in which layers 12 and 14 and 112, 114 are formed so that they are ultimately disposed within the openings. More importantly, the patent fails to expressly identify the process used to deposit the principal metal 28 and 128 of structures 31 and 131, respectively. Electroplating is not referenced in connection with this embodiment and, further, the patent even suggests that layers 12 and 14 may be omitted from the structures ('808 patent, column 5, lines 18-21 and 34-36). It therefore appears that the '808 patentee did not advocate a bulk electroplating process for depositing the principal metal in those instances in the metal structures are present in recesses in the surface of the workpiece.

The '498 Patent

The '498 patent includes a multi-layer interconnect structure that is formed in the micro-recessed structures disposed in the surface of a semiconductor workpiece. A metal seed layer 3 is disposed over a barrier layer 2 in the micro-recessed structures. The principal interconnect

metal 4 is deposited on the metal seed layer 3 using an electrolytic deposition process. The metal seed layer 3 has a thickness of approximately (0.10 microns; 1,000 Angstroms).

Notably, the '498 patent neither discloses nor suggests that such a thin seed layer may be enhanced prior to the bulk electroplating of the principal metal over its surface. Rather, the process sequence set forth in the '498 patent proceeds directly from the deposition of the seed layer to the electroplating of the bulk metal layer 4. Nor does the patent recognize any problem that may be associated with using a thin 100 nm seed layer, particularly in those instances in which the micro-recessed structures have high aspect ratios. In particular support of this statement, the Examiner is directed to the fact that seed layer 3 is illustrated in Figures 1C through 1D as being substantially conformal and without defects.

Not Claimed!

None of the references of record either disclose or suggest the enhancement of an ultra-thin seed layer having a thickness that is less than or equal to about 500 angstroms where the seed layer is ultimately used to electroplate a metal in micro-recessed structures in the surface of a microelectronic workpiece as set forth in independent claims 1, 58 and 67

Language directed to ultra-thin seed layer thicknesses that are ***less than or equal to about*** 500 angstroms in a process for filling micro-recessed structures in a surface of a microelectronic workpiece can be found in independent claim 1, as amended, and in new claims 58 and 67.

As previously set forth, the problems associated with ultra-thin seed layers become particularly acute when the seed layer must necessarily cover the walls of micro-recessed structures so that it can be used in a subsequent bulk electroplating of the principal metal. Although the '808 patent refers to a copper seed layer having a thickness of 500 angstroms, the

seed layer is not deposited to cover sidewalls of micro-recessed structures formed in the surface of the workpiece. Further, as noted above in the discussion of the '808 patent, the copper seed layer is directly used for bulk electroplating of the principal metal and is not subject to an intermediate enhancement process.

The '498 patent likewise neither discloses nor suggests the use of an ultra-thin seed layer having a thickness that is less than or equal to about 500 angstroms in a process in which the seed layer is used to bulk electroplate the principal metal into micro-recessed structures formed in the surface of the workpiece. Rather, the '498 patent employs a seed layer of 100 nm, a thickness that is approximately twice the upper limit of the thickness set forth in the claims _.

None of the remaining references either disclose or suggest enhancement of the ultra-thin seed layer as set forth in independent claims _. Applicant therefore submits that such claims and all claims dependent thereon are patentable over the art of record.

None of the references of record either disclose or suggest the enhancement of a seed layer having a thickness that is less than 500 angstroms as set forth in independent claims 16, 30, 49, 63 and 64

Claims 16 and 30, as amended, and new claims 49, 63 and 64, are not limited to processes in which micro-recesses are filled in a bulk electroplating process. Rather, such claims are generally independent of whether the surface of the workpiece is smooth or otherwise includes micro-recesses. However, these claims include language that limit their scope to instances in which the ultra-thin seed layer has a thickness that is less than 500 Angstroms (note that the upper thickness limit in connection with processes that bulk electroplate the principal metal into micro-recesses extends to initial seed layer thicknesses up to and including about 500 Angstroms). Additionally, these claims are limited in scope to those instances in which the

additional metal is deposited on the ultra-thin seed layer using a process that is different from the deposition process used to deposit the ultra-thin seed layer.

The '808 patent neither discloses or suggests that a seed layer having a thickness that is ***less than*** 500 angstroms (0.05 microns) may be deposited using a first deposition process (for example, without limitation, CVD, PVD, electroless plating, etc.) and subsequently enhanced in a second deposition process that is different from the first deposition process (for example, without limitation, PVD for the first deposition process and an electrochemical deposition process, such as electroplating, for the second deposition process). Rather, the '808 patent states that the initial copper seed layer must be "***at least*** about 0.05 micron thick". The patent thus teaches away from depositing an ultra-thin seed layer having a thickness that is less than 0.05 microns, suggesting that the copper seed layer should have a thickness that is greater than 0.05 microns.

Further, as noted above, the '808 patent does not identify any problems with the performance of initial seed layers that are below 0.05 microns thick when they are used in a bulk electroplating process. As set forth in the present patent application, the inventor has found that seed layers that are below 0.05 microns thick may include voids, peaks and valleys, etc., that render the seed layer unsuitable for subsequent electrochemical deposition, particularly, electroplating. Moreover, such problems become particularly acute at seed layer thicknesses of about 0.025 microns or less (see new claim 50, which is dependent on new claim 49). Since the '808 patent does not identify any problems with such ultra-thin initial seed layers, neither does it suggest a solution for such problems.

The '498 patent likewise neither discloses nor suggests the use of an ultra-thin seed layer having a thickness that is less than or equal to about 500 angstroms in a process in which the

seed layer is used to electroplate the bulk of the principal metal to fill micro-recessed structures formed in the surface of the workpiece. Rather, the '498 patent employs a seed layer of 100 nm, a thickness that is approximately twice the upper limit of the thickness set forth in independent claims 16, 30, 49, 63 and 64.

None of the remaining references either disclose or suggest enhancement of the ultra-thin seed layer as set forth in independent claims 16, 30, 49, 63 and 64. Applicant therefore submits that such claims and all claims dependent thereon are patentable over the art of record.

None of the references of record either disclose or suggest a process in which a seed layer is initially deposited on the surface of the workpiece using a first deposition process and in which the seed layer is subsequently enhanced by adding a metal that comprises the metal used in the initial seed layer using a second, different deposition process prior to bulk-electroplating of a metal as set forth an in independent claims _

Independent claims 68 and 69 have been added to the present application and are directed to a process sequence in which an ultra-thin seed layer is initially deposited on the surface of the workpiece using a first deposition process. The ultra-thin seed layer is subsequently enhanced by further deposition of a metal on the ultra-thin seed layer. The metal that is deposited on the ultra-thin seed layer for purposes of enhancement comprises the same metal that is used in the initial ultra-than seed layer. Such enhancement is accomplished using a second, different deposition process to add the further metal. The enhanced seed layer is then used in a bulk-electroplating process. These independent claims do not place an upper limit on the thickness of the ultra-thin seed layer.

Neither the '808 patent nor the '469 patent disclose or suggest, alone or in combination, that an ultra-thin seed layer can be enhanced to form an enhanced seed layer that is suitable for

subsequent electroplating as set forth in claims 67 and 68. Rather, as noted above, the seed layers used in each of these patent references are directly subject to electroplating of a bulk amount of the principal metal used to form the desired metal structure without regard to an intermediate enhancement step that may otherwise improve the quality of the electroplated film.

None of the remaining references either disclose or suggest enhancement of the ultra-thin seed layer as set forth in independent claims 67 and 68. Applicant therefore submits that such claims are patentable over the art of record.

Other arguments for patentability of the independent claims

Applicant notes that the foregoing arguments for patentability of the independent claims are directed to the principal distinctions between the independent claims and the art of record, but do not necessarily constitute an exhaustive list of all of the limitations found in the independent claims and dependent claims that distinguish them from the art. Rather, there are also other patentable distinctions present in certain of the claims of the present application that are not disclosed or suggested in the art of record. For example, the art of record neither discloses or suggests the enhancement of an ultra-thin seed layer using an alkaline electroplating process which is then followed by bulk deposition of a metal in an acidic electroplating process as found in independent claims 30 and 65, as well as certain dependent claims. The alkaline electroplating process is particularly suited for, although not limited to, enhancing ultra-thin seed layers that are disposed on a barrier material. It has been found that the resulting enhanced seed layer adheres particularly well to the underlying barrier material, but that the plating process in an alkaline bath is generally slower than the plating rate that can be achieved using an acidic

bath. Accordingly, the present inventor has disclosed a processing sequence that takes advantage of the adhesion benefits of the alkaline electroplating process as well as the electroplating rate benefits of the acidic electroplating process.

PETITION FOR A THREE-MONTH EXTENSION OF TIME

Applicant hereby requests a three-month extension of time to file a response to the Office Action dated July 9, 1999. Since January 9, 2000, is a Sunday, a response is due on or before January 10, 2000. The Commissioner is hereby authorized to charge Deposit Account 04-1644 for the fee for extension of time as well as all fees coming due as a result of the amendments submitted herewith.

Conclusion

In view of the foregoing, Applicant submits that all of the rejections/objections to the present application have been overcome by this Response. Applicant therefore respectfully requests reconsideration of the application and allowance of the claims. If the Examiner determines that there are still further issues that need to be addressed, he is encouraged to contact Applicant's representative, Bob Polit, at the telephone number set forth below.

Respectfully submitted,

Date: January 10, 2000

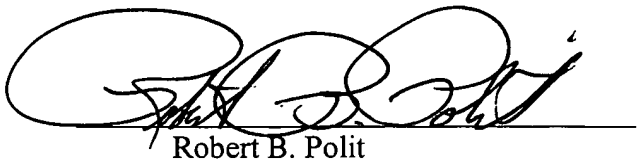

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Fig. 1

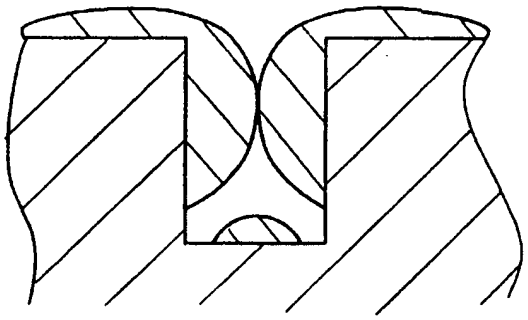

Fig. 2A

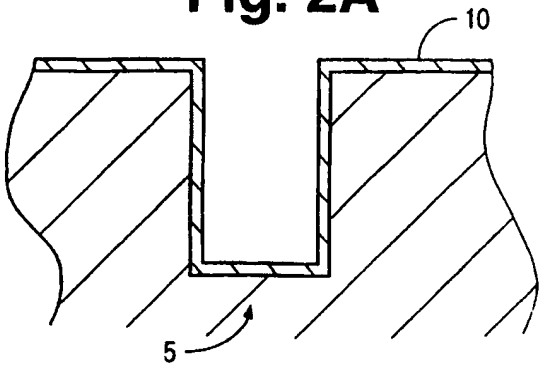

Fig. 2B

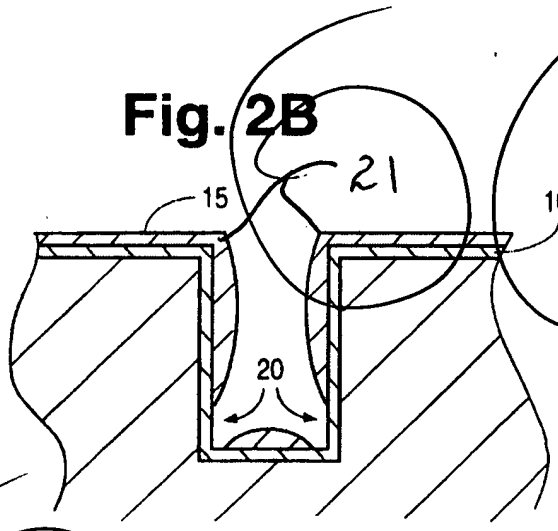

Fig. 2C

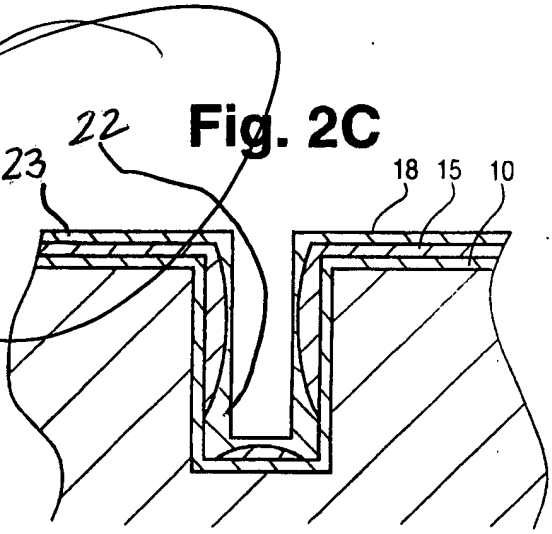

Fig. 2D

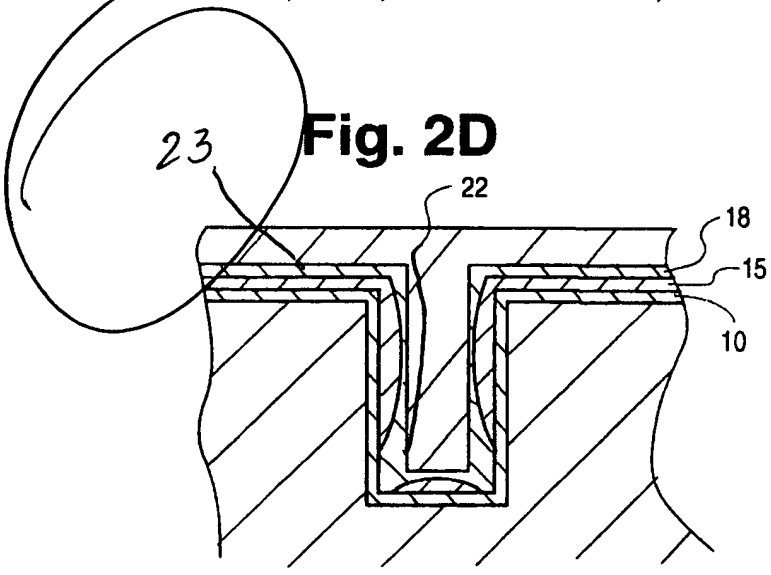

Fig. 2E